Center Independent Research & Development: GSFC IRAD

Controlled Thermal Expansion Alloys

Completed Technology Project (2011 - 2014)

Project Introduction

There has always been a need for controlled thermal expansion alloys suitable for mounting optics and detectors in spacecraft applications. These alloys help provide the stability required to capture the stunning images we have come to expect from our observatories and satellites such as the Hubble Space Telescope (HST) and the series of Geostationary Operational Environmental Satellites (GOES), and those we hope to see with the James Webb Space Telescope (JWST), Next Generation X-ray Observatory (NGXO), Advanced Technology Large-Aperture Space Telescope (ATLAST) and others. Without them, the precision instruments on these spacecraft would produce blurred images and low resolution spectra. In practice, these alloys would be fashioned into support structures for optics or detector baseplates, and their compositions designed to match the dimensional change over a given temperature range to minimize distortion due to thermal mismatch stresses. This effort addressed the need to invent a process to design an alloy that performs to a specific coefficient of thermal expansion (CTE) requirement. Of particular interest is the lower CTE range where silicon, as well as many of the glasses we use for optics, are required to perform.

This first part of this effort investigated the iron-nickel binary system with varying nickel content over a range of CTE from 0.6ppm/°C to 10.0ppm/°C. Figure 1 shows a comparison of calculated values of room temperature CTE for binary Fe-f(Ni) alloys based on the two gamma state ferromagnetic model for the face-centered cubic Fe-Ni austenite matrix, with one-hundred year old data from the experimental work of Guillaume. Both the calculation and the early experimental data indicate that the CTE of Fe-Ni binary alloys vary continuously with nickel content in a smooth and predictable manner.

The second part of this effort determined experimentally the functional relationship between Ni content and CTE for the binary Fe-Ni system. This was achieved by manufacturing a series of test alloys using high-precision melt metallurgical techniques. The test alloys were heat treated by the Goddard Space Flight Center’s (GSFC) Materials Engineering Branch (MEB) and CTE coupons were machined by GSFC’s Advanced Manufacturing Branch. Microstrain was measured as a function of temperature from 300K to 23K using the MEB interferometer. Figure 2 shows an example of a secant CTE calculated from these microstrain measurements over the temperature range 10°C to 30°C.

Anticipated Benefits

This work is cross-cutting and has application for minimizing distortion in optics and sensors for Heliophysics, Astrophysics (VNC and NGXO), Earth Observation (AGES) and Gravitational Wave Missions (LISA Pathfinder and LISA).

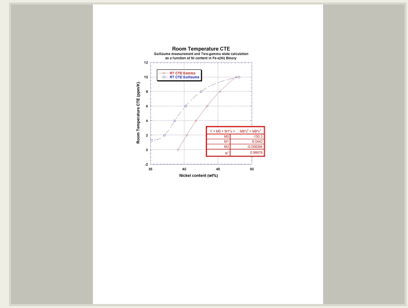

Figure 1. Comparison of room temperature CTE calculated from the two gamma state model with experimental measurements from Guillaume.

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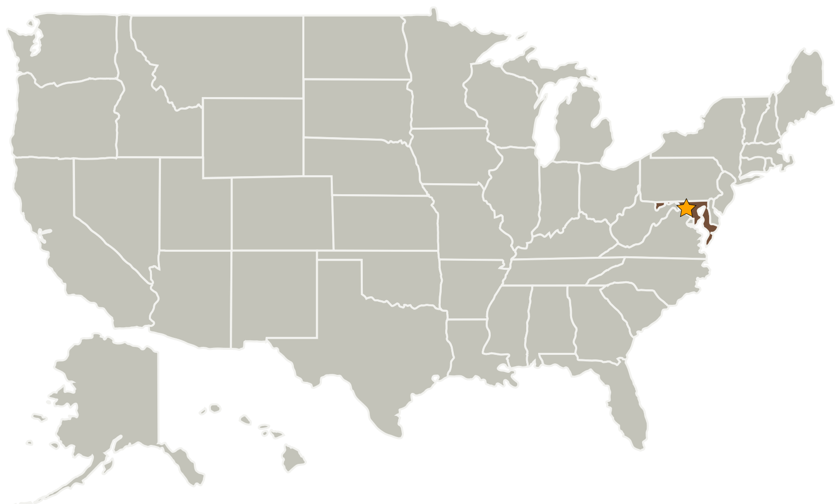
Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
★Goddard Space Flight Center(GSFC)	Lead Organization	NASA Center	Greenbelt, Maryland

Primary U.S. Work Locations
Maryland

Organizational Responsibility

Responsible Mission Directorate:

Mission Support Directorate (MSD)

Lead Center / Facility:

Goddard Space Flight Center (GSFC)

Responsible Program:

Center Independent Research & Development: GSFC IRAD

Project Management

Program Manager:

Peter M Hughes

Project Manager:

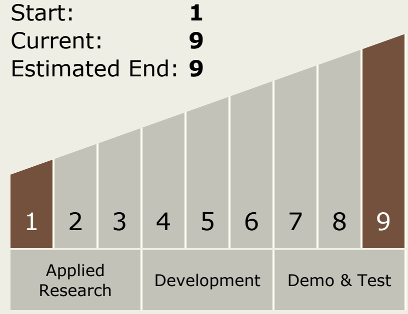
Theodore D Swanson

Principal Investigator:

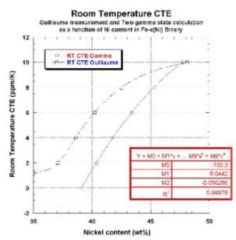
Timothy A Stephenson

Technology Maturity (TRL)

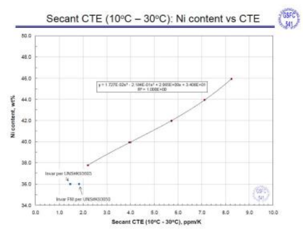
Start: **1**
Current: **9**
Estimated End: **9**



Images



Calculation
Figure 1. Comparison of room temperature CTE calculated from the two gamma state model with experimental measurements from Guillaume.
(https://techport.nasa.gov/image/2623)



Experiment
Figure 2. Nickel content in Fe-Ni binary as a function of Secant CTE from 10°C to 30°C.
(https://techport.nasa.gov/image/2624)

Project Website:

http://aetd.gsfc.nasa.gov/

Technology Areas

Primary:

- TX08 Sensors and Instruments
  - └ TX08.2 Observatories
    - └ TX08.2.1 Mirror Systems